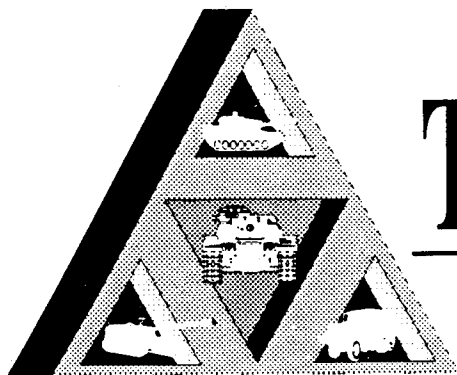


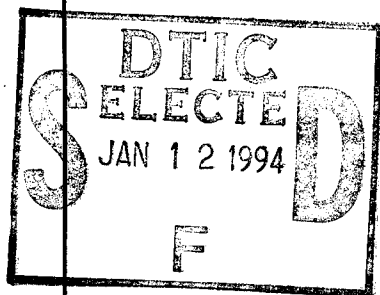
# TARDEC



## Technical Report

No. 13614

### Improved Antifreeze for Combat/Tactical Vehicles



December 1994

By **Dwayne Davis**  
USA Tank Automotive Command  
Mobility Technology Center Belvoir

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## Section 1 Objective and Background

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The objective of this program was to improve the performance of the current MIL-A-46153 military antifreeze by changing its formulation. Specifically, the thrust was to improve its aluminum corrosion protection. The current MIL-A-46153 formulation was developed in the 1950's when heavy-duty engines and water pumps were constructed of cast iron, with brass/copper radiators. Today, heavy-duty engine manufacturers are employing aluminum alloys at an ever increasing rate to reduce total engine weight and increase overall engine efficiency. The use of aluminum alloys can be found in radiators, cylinder heads, water pump housings, manifolds, and engine blocks.<sup>1</sup> With this increase of aluminum use among the heavy-duty engine manufacturers, aluminum components are now found in heavy-duty engine systems used to power military vehicles fleets.

The present MIL-A-46153 military antifreeze formulation<sup>2</sup> contains no "aluminum specific" corrosion inhibitors. The performance of the MIL-A-46153 formulation was evaluated in a 1988 field survey<sup>3</sup> involving 100 military installations throughout the United States and abroad. The results of the survey revealed that MIL-A-46153 performs satisfactorily. For instance, 80% of the installations found the current MIL-A-46153 military antifreeze to be an effective product. However, the remaining 20% of the survey participants felt that MIL-A-46153 needed improving, with some suggesting that the current antifreeze provides minimal corrosion protection for aluminum components. In addition to these suggestions, MIL-A-46153 fails the ASTM laboratory test for heat transfer corrosion of aluminum cylinder heads during engine operation, D4340.<sup>4</sup> ASTM guidelines recommend a new coolant pass this test with a value of 1mg/cm<sup>2</sup>/week or less. The current MIL-A-46153 military antifreeze consistently fails D4340 with values in ranging between 20 to 40mg/cm<sup>2</sup>/week. Given the repeated failures of the D4340 test, the average results of the survey, and the introduction of aluminum in heavy-duty applications, a program was initiated to address the feasibility of improving the MIL-A-46153 formulation to enable it becoming an effective antifreeze in the future.

## Section 2 Approach

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Several commercial antifreeze formulations were examined to determine which inhibitor combinations give the best aluminum protection and general corrosion protection. Both heavy-duty and light-duty, automotive antifreezes were examined. Professionals in the commercial engine antifreeze industry were consulted. In addition, technical papers concerning antifreeze formulations were reviewed.<sup>5,6,7,8</sup> As a guide in developing an improved MIL-A-46153 military antifreeze, target pH and reserve alkalinity (RA) limits were tentatively chosen. For example, various literature sources<sup>9,10,11,12</sup> suggest that moderately alkaline antifreeze solutions (i.e., pH between 8.5 and 10.5) are more conducive for aluminum corrosion protection than acidic solutions (i.e., pH < 6). For the RA or buffer capacity, a high RA similar to the existing MIL-A-46153 was desired because of the several decades of reliable performance this high RA has provided the military's ground fleet.

After experimental formulations were prepared, their pH and RA values were measured as a concentrate and as a 50-50 aqueous solution. If the pH and RA were considered acceptable, additional tests were conducted on each of the candidate experimental formulations. For example, the ASTM glassware corrosion test, (D1384), and a ASTM heat-rejecting surface test (D4340) were conducted to determine the corrosion protection characteristics for each of the formulations. If the candidate formulation successfully passed these two tests, further testing was done to characterize the formulation physically and chemically (e.g., foaming characteristics, boiling point, specific gravity, etc.). If a candidate formulation met all the above criteria, it was selected for final laboratory systems testing and eventual field evaluation.

Fourteen (14) original experimental formulations were prepared. A list of the 14 formulations is shown in Table 1. The mixing procedure consisted of first combining the borax, the antifoam additive, and the ethylene glycol (EG). This mixture was stirred on a hot plate at a temperature between 50° and 60°C in a 4000-mL, heavy-duty beaker until the solution gave a clear appearance. Initially, the first nine (9) formulations were stirred by hand with a stirring rod. For subsequent samples, a hot plate with a magnetic stirrer and a stirring bar were employed because the constant agitation allowed the components to dissolve faster. The total time elapsed during mixing was between 35 to 45 minutes after initial heating began. The remaining inhibitors were combined with the "added water" in a 500-mL beaker. This solution was stirred and heated on a hot plate between 40° and 55°C until the solution became clear. The total time elapsed during mixing was between 25 to 35 minutes after initial heating began. Once the two solutions appeared clear, the contents of the smaller beaker were combined in the larger beaker and the resultant mixture stirred an additional 30 minutes to an hour depending on how fast the solution became clear in appearance.

Table 1. Candidate Formulations (weight percent)

Compound	#1	#2	#3	#4	#5	#6	#7
Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub> ·10H <sub>2</sub> O	4.0	4.0	2.0	4.0	2.0	2.0	2.0
Na <sub>3</sub> PO <sub>4</sub> ·12H <sub>2</sub> O	0.3	0.3	0.3	0.3	0.3	0.3	0.3
NaNO <sub>2</sub>	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NaNO <sub>3</sub>	0.2	0.2	0.2	—	—	—	—
Na <sub>2</sub> MoO <sub>4</sub> ·2H <sub>2</sub> O	—	—	—	—	—	—	0.3
NaTT (50%aq)	—	0.2	0.2	0.2	0.25	0.25	0.25
DiNaMBT (50%aq)	0.2	—	—	—	—	—	—
Na <sub>2</sub> SiO <sub>3</sub> ·9H <sub>2</sub> O	0.3	0.3	0.3	0.3	0.3	0.3	0.3
NaOH	—	—	—	—	—	0.2	—
Antifoam	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Added Water	5.0	2.4	3.3	2.5	2.0	2.0	2.0
Ethylene Glycol	Bal	Bal	Bal	Bal	Bal	Bal	Bal

pH Concentrate	6.6	6.4	6.4	6.5	6.6	6.8	6.8
RA Concentrate, mL	29.3	31.3	16.8	29.8	17.4	19.5	17.6
pH 50/50 Solution	7.8	7.8	7.8	7.7	8.1	8.3	8.1
Freeze Point, °F <sup>1</sup>	-25	-31	-30	-32	-32	-31	-32

<sup>1</sup>Freeze point determined with a hand held refractometer as prescribed in ASTM standard method D3321.

Table 1. Candidate Formulations (weight percent) (continued)

Compound	#8	#9	#10	#11	#12	#13	#14
Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub> ·10H <sub>2</sub> O	1.1	1.1	1.1	—	1.0	2.5	2.5
Na <sub>3</sub> PO <sub>4</sub> ·12H <sub>2</sub> O	0.6	0.6	—	0.6	0.6	0.3	0.5
NaNO <sub>2</sub>	0.5	0.3	0.3	0.3	0.25	0.3	0.3
NaNO <sub>3</sub>	0.5	0.3	0.3	0.3	0.25	0.3	0.3
Na <sub>2</sub> MoO <sub>4</sub> ·2H <sub>2</sub> O	—	—	0.6	1.1	—	—	—
NaTT (50%aq)	0.25	0.25	0.25	0.25	0.25	0.25	0.3
DiNaMBT (50%aq)	—	—	—	—	—	—	—
Na <sub>2</sub> SiO <sub>3</sub> ·9H <sub>2</sub> O	0.3	0.3	0.3	0.3	0.3	0.3	0.5
NaOH	0.4	0.2	0.1	0.1	0.1	0.1	0.1
Antifoam	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Added Water	2.1	2.1	2.1	2.1	2.0	2.0	2.0
Ethylene Glycol	Bal	Bal	Bal	Bal	Bal	Bal	Bal

pH Concentrate	12.2	11.7	9.1	12.2	11.0	6.6	8.9
RA Concentrate, mL	23.6	17.7	12.4	11.8	16.0	23.3	27.3
pH 50/50 Solution	12.2	11.7	8.9	12.1	11.0	8.2	8.5
Freeze Point, °F	-34	-35	-40	-33	-32	-33	-35



Of the 14 formulations prepared only four (4) were judged as acceptable experimental candidates for further evaluation. The remaining formulations were eliminated based on their unsatisfactory appearance (e.g., precipitation or cloudiness), low pH, or low RA values. For example, formulation #1 was initially clear and bright, but formed a white crystalline precipitate after sitting several hours. The precipitate was attributed to the copper corrosion inhibitor, disodium 2,5-dimercapto-1,3,4-thiazole (DiNaMBT), being insoluble in ethylene glycol. This was verified by the successful preparation of formulation #2 which substitutes sodium tolytriazole for DiNaMBT and has less added water. No precipitate formed in this solution. The DiNaMBT is a relatively new inhibitor and was tested to determine if it would provide additional benefits compared to the commonly employed copper inhibitors sodium tolytriazole and sodium mercaptobenzothiazole. Formulations #2 through #6, and #9 through #13 did not result in the pH and RA being within the desired ranges. Formulations #7, #8, and #14 were considered acceptable and tested further. Results of the heat-rejecting aluminum tests (i.e., D4340) are shown in Table 2. The results of the three experimental candidate formulation showed a significant improvement over the current MIL-A-46153 formula. The new formulations also meet the ASTM recommended corrosion rate for D4340.

**Table 2. Heat-Rejecting Aluminum Corrosion Test, D4340**

Sample	#7	#8	#14	Current MIL-A-46153
pH Before Test	8.6	12.1	9.1	8.3
pH After Test	8.6	11.6	8.6	8.2
RA Before Test	4.3mL	5.8mL	6.1mL	7.0mL
RA After Test	3.9mL	5.0mL	5.9mL	7.0mL
Corrosion Rate (mg/cm <sup>2</sup> /week)	+0.8{1}	+1.3	+0.6	29.2
ASTM Recommended Corrosion Rate	1.0			

In addition to the D4340 screening test, the glassware corrosion D1384 was also performed on formulation #14. The results are shown in Table 3. The glassware results for formulation #14 were comparable to the current MIL-A-46153 formulation and are within the ASTM recommended weight losses. However, funding constraints prevented the additional glassware corrosion testing of formulations #7 and #8 and final laboratory evaluation of these candidate formulations.

**Table 3. Glassware Corrosion Test D1384, weight loss/specimen, mg**

	Copper	Solder	Brass	Steel	Cast Iron	Cast Aluminum
#14	+3	10	+2	+1	1	+6
MIL-A-46153	1	7	3	2	1	+1
ASTM maximum	10	30	10	10	10	30

**Table 4. MIL-A-46153 Formulation**

Compound	Weight %
$\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$	4.0
$\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$	0.3
$\text{NaNO}_2$	—
$\text{NaNO}_3$	—
NaTT (50%aq)	0.25
$\text{Na}_2\text{SiO}_3 \cdot 9\text{H}_2\text{O}$	—
NaOH	—
Antifoam	0.02
Total Water	5.0
Ethylene Glycol, min	77.6
Total vicinal glycols, min	87.6

## Section 3 Conclusions

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Because of the loss of technology base resources, this effort could not be completed. However, the program did produce three (3) candidate formulations (i.e., #7, #8, and #14) which could be used to upgrade the current MIL-A-46153 military antifreeze. More extensive laboratory (i.e., D2809 aluminum water pump cavitation test and D2570 simulated service test) are required to verify the performance of these formulations.

While the MIL-A-46153 antifreeze improvement program was being conducted, a parallel effort to develop a less toxic alternative antifreeze was initiated. Development work on this project began in FY93. This effort was part of the Hazardous Waste Minimization Program of the Defense General Supply Center (DGSC) in Richmond, Virginia, and was funded through their Defense Environmental Restoration Account appropriations. The current formulation for MIL-A-46153 uses ethylene glycol (EG) as its base material. Its formulation is given in Table IV. Because of its relatively high toxicity,<sup>13</sup> state and federal regulatory restrictions on EG have increased steadily in recent years.<sup>14</sup> As a result, DGSC requested<sup>15</sup> that this office consider developing a less hazardous antifreeze. For the alternative antifreeze, propylene glycol (PG) was chosen as the less toxic base material.<sup>16</sup> Because of PG's similar chemical characteristics compared to EG, the research and development accomplished during the program to improve MIL-A-46153 will be directly applied to the PG antifreeze effort. For example, PG's slightly different solubility characteristics compared to EG will enable the improved corrosion inhibitor technology that was developed to be transitioned directly to the PG antifreeze study.

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2ND MARINE DIV  
PSC BOX 20090  
CAMP LEJEUNE NC 28542-0090

1 CDR  
1ST MARINE DIV  
CAMP PENDLETON CA 92055-5702

#### DEPARTMENT OF AIR FORCE

1 HQ USAF/LGTV  
ATTN VEH EQUIP/FACILITY  
1030 AIR FORCE PENTAGON  
WASHINGTON DC 20330-1030

1 AIR FORCE HEEP MGMT OFC  
615 SHSQ/LGTY MEEP  
201 BISCAYNE DR STE 2  
ENGLIN AFB FL 32542-5303

1 5A ALC/SFT  
1014 ANDREWS RD STE 1  
KELLY AFB TX 78241-5603

1 WR ALC/LVRS  
225 OCNULGEE CT  
ROBINS AFB GA 31098-1647

#### DEPARTMENT OF DEFENSE

1 DIRDLA  
ATTN DLA NNDI  
1 ATTN DLA MNSB  
CAMERON STA  
ALEXANDRIA VA 22304-6100

1 CDR  
DEFENSE GEN SUPPLY CTR  
ATTN DGSC SSA  
1 ATTN DGSC SSC (W SMITH)  
1 ATTN DGSC STAC (C MYERS)  
8000 JEFFERSON DAVIS HWY  
RICHMOND VA 23297-5678

12 DEFENSE TECH INFO CTR  
CAMERON STATION  
ALEXANDRIA, VA 22314

20 MOBILITY TECH CENTER BELVOIR  
ATTN AMSTA RBF  
FORT BELVOIR, VA 22060

1 MDW DESK LOG  
BLDG 17 DR 10  
ATTN L FIORENTINO  
CAMERON STATION  
ALEXANDRIA VA 22304

1	62 TRNS LGTM 761 BATTERY RD BLDG 779 ATTN SGT TILLMANN MCHORD AFB WA 98438-1127	1	III CORP G-4 ATTN AFTZ GL (CPT YOCKUM) FT HOOD TX 76546
1	US ARMY CORP OF ENGRS ATTN CAMM OP R PO BOX 2288 MOBILE AL 36628-0001	1	NWR DEPT NAVAL AIR STATION ATTN S KOWALSKI FALLON NV 09406-5000
1	EDGAR POE NATL RES ENVRMT AFFR BLDG 1059 MARINE CORP TWENTY NINE PALMS CA 92278-5000	1	ADJT GENL IOWA CAMP DODGE ATTN AGIA FAC E (GAICH) 7700 BEAVER DR JOHNSTOWN IA 50131
1	857TH CES DEVE BLDG 445 MINOT AFB ND 58705-5000	1	MAJ D CORNELL ATTN OC LAC EMW TINKER AFB OK 73145
1	MARINE CORP LOG BASE NATL RES ENVRL OFFICE ATTN AL HARGROVE CODE 560 ALBANY GA 31704	1	CDR 10TH MOUNTAIN DIV DEH ENVRL OFFICE ATTN AFZX DH E FT DRUM NY 13602-5000
1	DEH ENVRL DIVISION ATTN ATZR E (SCOTT) FT SILL OK 73503-5100	1	JILL RUSH 436 CES DEEV DOVER AFB DE 19902-5516
1	MMC (MSWSES) FRANCISO TADAY SAFETY CODE 0009 PORT HUENEME CA 93043	1	MIKE MARKER 2750TH ABW EMC WRIGHT PATTERSON AFB OH 45433-5000
1	DEH ATTN BRMD (L CLEMONS) FT DRUM NY 13602-5097	1	ARMY RES MAIT SUP SHOP ATTN AMSA5 (F ELLESER) 2800 CRESTLINE RD FT WORTH TX 76107
1	HQ USAF CEV BOLLING AFB ATTN CPT J HROMOWYK WASHINGTON DC 20332-5000	1	ERNEST EDDY HHC 8TH USA ARMY PSC303 PO BOX 78 APO AP 96205-0078
1	SAFETY LINE MAGAZINE CODE 722 EDITOR RAE MAGILL NAVAL SAFETY CTR NAS NORFOLK VA 23511	1	CDR HHB 1ST BATTLN 43RD ADA ATTN BMO FT BLISS TX 79916
1	HQ MACK LEMSB ATTN SGT SHAW SCOTT AFB IL 62225-5001	1	CDR HHB 1ST BATTLN 62ND TRANS CO FT BLISS TX 79916
1	US ARMY FT GREELEY ATTN APVR FG DE (ROSSI) SEATTLE WA 98733	1	CDR NEW CUMBERLAND ARMY DEP DIR MAINT ATTN SDSNC M NEW CUMBERLAND PA 17070
1	NATNL GUARD INDIANA 2002 S HOLT RD ATTN MD FE EN (CPT ORE) INDIANAPOLIS IN 46241-0326	1	MK1 BURNS CGSTA BURLINGTON DEPOT ST BURLINGTON VT 05401
1	LETTERKENNY ARMY DEPOT ENVRL MAN DIV BLDG 363 ATTN SDSLE ENE (UPSTAIN) CHAMBERSBURG PA 17201	1	BILL CONN HQ 18TH AIRBORN CORP FT BRAGG DEH ATTN AFZA DEDV FT BRAGG NC 28307-5000
1	SUPPLY & SERVICE DIV ATTN ATZC ISL S FT BLISS TX 79916	1	CHIEF NG BUREAU ATTN NGB ARL SM (MADDEN) ARLINGTON HALL STATION BLDG T-420 ARLINGTON VA 22304-1382



<p>1 BRH MED CLINIC INDRL HYGNT MARINE CORP LOG BASE BARSTOW CA 92311</p> <p>1 MSG M KRIZ 5TH MAINT SQUAD MINOT AFB ND 58704</p> <p>1 LESTER DZIUK ATTN SA LAC SFTT KELLY AFB TX 78241-5000</p> <p>1 DAVID DAVIS US ARMY ENVL HYG AGY WASTE DISPOSAL APG MD 21010-5422</p> <p>1 JOHN SHIMP DEH BLDG 408 ENVRL &amp; NATL RES DIV FT FILEY KS 66442-6016</p> <p>1 CDR ANNISTON ARMY DEPOT DIR MAINT ATTN SDSAN M ANNISTON AL 36201-5000</p> <p>1 MSG T SMITH 60TH MAW MASE TREVIS AFB CA 94535</p> <p>1 PEGGY HARLOWE CONN NG 360 BROAD ST HARTFORD CT 06805-3795</p> <p>1 VINCENT TUNG 8403 LEE HWY MERRIFIELD VA 22080-8101</p> <p>1 LTC MARK HAGUE COLORADO NATL GUARD 6848 REVERE PARKWAY ENGLEWOOD CO 80112</p> <p>1 WASHINGTON ST MIL DEPT ATTN FMO ENGR G MATTHEWS BLDG 33 CAMP MURRAY TACOMA WA 98430-5054</p> <p>1 DAVE ELLIOT SAN ANTONIO ALC ATTN LDPT KELLY AFB TX 78241</p> <p>1 CDR LETTERKENNY ARMY DEP ATTN SDSLE MME (K GULYAS) BLDG 1C CHAMBERSBURG PA 17201-4150</p> <p>1 JIM PARKER NC DEPT TRANS EQUIP UNIT 4809 BERYLE ST RALEIGH NC 27600</p> <p>1 KEN WALLER AEROSPACE FUELS LAB C BLDG 1 10 PARK AVE MUKILTEO WA 78275</p>	<p>1 CDR TOOEELE ARMY DEPOT DIR MAINT ATTN SDSTE M TOOEELE UT 84074-5011</p> <p>1 CDR USCG GRP UPR MISS 221 MISSISSIPPI DR ATTN CHIEF CANDLER KEOKUK IA 52632</p> <p>1 NICKS KNOPE WR ALC LZEC ROBBINS AFB GA 31098</p> <p>1 CDR TOBYHANNA ARMY DEPOT ATTN PAT TIERNEY TOBYHANNA PA 18466-5075</p> <p>1 NSS FACLT NEW LONDON CONN NAVSEA OFF (KING) PO BOX 300 GROTON CT 06349</p> <p>1 AIR NATL GUARD ATTN ANGRC LGMSE (VILLA) 3500 FETCHT AVE ANDREWS AFB MD 20331-5151</p> <p>1 CIVIL ENGR SUPP ATTN S JOHNSON CODE 15741 PORT HUNEME CA 93043-5000</p> <p>1 ADJ GENRL PENN US PRPTY OFF FIS PENN ATTN CW2 R SCHAFER DEPY MILITARY AFFRS ANNVILLE PA 17003-5002</p> <p>1 HQ FT DEVENS ATTN AFZD EM (C WILLIAMS) PO BOX 19 FT DEVENS MA 01433</p> <p>1 LETTERKENNY ARMY DEPOT ENVRL MAN DIV BLDG 363 ATTN SDSLE ENE (UPSTAIN) CHAMBERSBURG PA 17201</p> <p>1 USALAL ATTN AMXLA C E DV K DESAUSPELS FT DEVENS MA 01433-5880</p> <p>1 FACLTYS ENGRG LTC HURELY US CG TRNG CTR CAPE MAY NJ 08204</p> <p>1 WYOMING ARMY NG SURFACE MAINT PO BOX 1709 ATTN CPT SHEPPARD CHEYENNE WY 02003-1709</p> <p>1 US ARMY CORP ENGRS LA CLAIR BASE PLANT ATTN OD MP (J WILSON) PO BOX 2004 ROCK ISLAND IL 61204-2004</p>
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1	CORKY CROVATO KASCO FUEL MAINT 4481 BEECH RD TEMPLE HILLS MD 20748	1	AMC INSTLNS SER ACT ATTN AMXEN U (BEDTRAM) ROCK ISLAND IL 61299
1	FPPF CHEMICAL CO ROBERT MILLER 32 MONROE AVE ROSELAND NJ 07068	1	CDR DUGWAY PRVG GRD ATTN EN MM (JACK DAVIS) DUGWAY UT 84022
1	FINISH THOMPSON INC PETER SCANTLEBURY 921 GREENGARDEN RD ERIE PA 16501-4478	1	WYNN OIL CO TECH SERVS JIM BAYLOR 1151 W FITTH ST AZUZA CA 91702
1	LTC CHARLES SMITH HQ USMC CODE LFS-2 WASHINGTON DC 20380	1	COOPER ENTERPRISES BOB SWEENEY 2122 COUNTRY CLUB DR SUITE 280 CARROLLTON TX 75006
1	USA ARMY LOG ASS OFFC ATTN AMXLA C E JK AL NELSON PO BOX 10010  FT JACKSON SC 29207-0010	1	FINISH THOMPSON INC PRESIDENT CEO H DAVID BOWES 921 GREENGARDEN RD ERIE PA 16501-1591
1	TOOELE ARMY DEPOT ATTN SDSTE PAQ (D COX) TOOELE UT 84074	1	KLEER FLO CO PRESIDENT WALLACE HILGREN 15151 TECHNOLOGY DR EDEN PRAIRIE MN 55344
1	TOOELE ARMY DEPOT BLDG 113 ATTN R RAFMUSSEN TOOELE UT 84074	1	188 FG LGTM 4850 LEIGH AVE ATTN SMS MITCHEL FT SMITH AR 72903
1	JENS KNUDSEN ATTN GC LGTM TOOLEY AFB GREENLAND 12 SWSAPO AE 09704-5000	1	NELS PALM AMER FLUID TECH 9 FLETCHER ST CHELMSFORD MA 01824
1	RENE WIBE CHEMIST BG PRODUCTS INC 701 S WICHITA ST WICHITA KS 67213	1	89TH TRANS LGTM 3427 PENN AVE ATTN SSGT C DOLLAR ANDREWS AFB MD 20331-5005
1	RASCO GERALD ESKELEND CEP 1635-3 WOODSIDE DR WOODBRIIDGE VA 22191	1	ARMY PET CTR ATTN PET READS DIV (WARD) NEW CUMBERLAND PA 17070-5008
1	MARVIN LEATH ASS ROBERT NOVAGRATZ SUITE 300 ONE MASS AVE NW WASHINGTON DC 20001	1	NAVAL WARFARE CTR DEPT CODE SR 41 ATTN WALT KOEHLER LAKEHURST NJ 08733
1	FIRST BRANDS CORP COOLANT DEVE PETER WOYCIESJES 55 FEDERAL RD DANBURY CT 06810	1	ALBERT MORALES ATTN LDEE SALAC KELLY AFB SAN ANTONIO TX 78241
1	GARY SNYDER 615 SMSQ LGTV MEEP 201 BISCAYNE RD SUITE 2 EGLIN AFB FL 32542-5303	1	RALPH PHIPPS NREA BRANCH 3040 MCCAWLEY AVE QUANTICO VA 22134
1	DEF FUELS OFF ALASKA 6920 12TH ST ATTN FUELS LAB (SOHLBURG) ELMENDORF AFB ALASKA 99506-2570	1	TOM HACKNEY PUBLIC WORKS DEPT TRANS DIV CODE W80 NAVAL SURF WARFARE CTR DALHGRAN VA 22448-5000

- 1 KANSAS ARMY NATL GUARD  
CSMS  
ATTN D CRUMPTON  
131 W 127TH ST  
TOPEKA KS 66611-1159
- 1 GARY AKASAKI  
DIR PUBLIC WORKS  
ENVRL OFF USASCH  
FT CHESTER HI 96858-5000  
STOP 253
- 1 ERNIE BRANDT  
DIR LOG MAINT DIV  
FT RICHARDSON AK 99505
- 1 ADJ GENL PENN  
ATTN SSCMO (REMMINGER).  
BLDG 9-68  
FT INDIANTOWN GAP  
ANNVILLE PA 17003-5002
- 1 NATL GUARD BUREAU  
ATTN NGB ZPF (LTC SMITH)  
2500 ARMY PENTAGON  
WASHINGTON DC 20310-2500
- 1 USPNFO  
ATTN DSJ PC (REDHORSE)  
BLDG 7100 CAMP ROBINSON  
NORTH LITTLE ROCK AR  
72118-2200
- 1 MANNY RUYZ  
49 CES CEV  
550 TAVOSA AVE  
HOLLOMAN AFB NM  
88330-8450